

CRITICAL ITEMS LIST (CIL)

No. 10-02-01-33R/01

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1
SUBSYSTEM:	Nozzle Subsystem 10-02	PART NAME:	Fixed Housing-to-Aft End Ring Joint, Metal
ASSEMBLY:	Nozzle and Aft Exit Cone 10-02-01		Components (1)
FMEA ITEM NO.:	10-02-01-33R Rev M	PART NO:	(See Section 6.0)
CIL REV NO.:	M (DCN-533)	PHASE(S):	Boost (BT)
DATE:	10 Apr 2002	QUANTITY:	(See Section 6.0)
SUPERSEDES PAGE:	337-1ff.	EFFECTIVITY:	(See Table 101-6)
DATED:	31 Jul 2000	HAZARD REF.:	BN-03
CIL ANALYST:	B. A. Frandsen	DATE:	
APPROVED BY:			

RELIABILITY ENGINEERING: K. G. Sanofsky 10 Apr 2002

ENGINEERING: B. H. Prescott 10 Apr 2002

- 1.0 FAILURE CONDITION: Failure during operation (D)
- 2.0 FAILURE MODE: 1.1 Structural failure of metal components
- 3.0 FAILURE EFFECTS: Seal leakage, joint deformation and loss of nozzle causing thrust imbalance between SRBs and loss of RSRM, SRB, crew, and vehicle

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Nonconforming dimensions	
1.1.1	Initial manufacturing dimensions	A
1.1.2	Metal dimensions reduced by corrosion and/or refurbishment	B
1.2	Nonconforming material	
1.2.1	Improper heat treatment	C
1.2.2	Hydrogen embrittlement of bolts	D
1.2.3	Nonconforming voids, inclusions, or other material defects	E
1.3	Stress-corrosion cracking	F
1.4	Improperly-installed bolts	G
1.5	Transportation, handling, or assembly damage	H
1.6	Fatigue	I
1.7	Improper assembly techniques	J
1.8	Damage to threads	K

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5.0 REDUNDANCY SCREENS:

SCREEN A: N/A
 SCREEN B: N/A
 SCREEN C: N/A

6.0 ITEM DESCRIPTION:

1. The Fixed Housing and the Aft End Ring are steel components and are a part of the Nozzle Assembly, Final. They are assembled together with screws creating a metal-to-metal joint (Figures 1 and 2). Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U79324	Bearing Assembly, Nozzle-Flexible			1/motor
1U79149	Nose-Throat-Bearing Cowl Assembly, Nozzle			1/motor
1U79153	Nose-Throat-Bearing-Cowl-Housing Assembly, Nozzle			1/motor
1U79150	Housing Assembly, Nozzle Fixed			1/motor
1U52833	Aft End Ring	D6AC Steel	STW4-2709	1/motor
1U52945	Housing, Nozzle Fixed	D6AC Steel	STW4-2709	1/motor
1U77640	Segment, Rocket Motor, Aft			1/motor
1U76887	Pin, Spring	Steel, CRES 420	MS16562	A/R
1U51369	Washer, Special	4130 Steel		72/motor
1U76385	Screw	Alloy Steel with Cadmium Plating	FF-S-86 NAS 1351 QQ-P-416	72/motor
8U50800	Shipping Kit-Segment Corrosion-Preventive Compound and O-ring Lubricant	Heavy Duty Calcium Grease	STW5-2942	A/R
	Steel, Alloy, High Strength, D6AC	D6AC Steel	STW4-2606	A/R
	Sealant, Polysulfide	Synthetic Rubber, Polysulfide	STW5-9072	A/R

6.1 CHARACTERISTICS:

1. The main structure of the exhaust nozzle assembly consists of various steel and aluminum forgings. These parts support the bearing assembly, nozzle throat, and exit cone.

7.0 FAILURE HISTORY/RELATED EXPERIENCE:

1. Current data on test failures, flight failures, unexplained failures, and other failures during RSRM ground processing activity can be found in the PRACA Database.

8.0 OPERATIONAL USE: N/A



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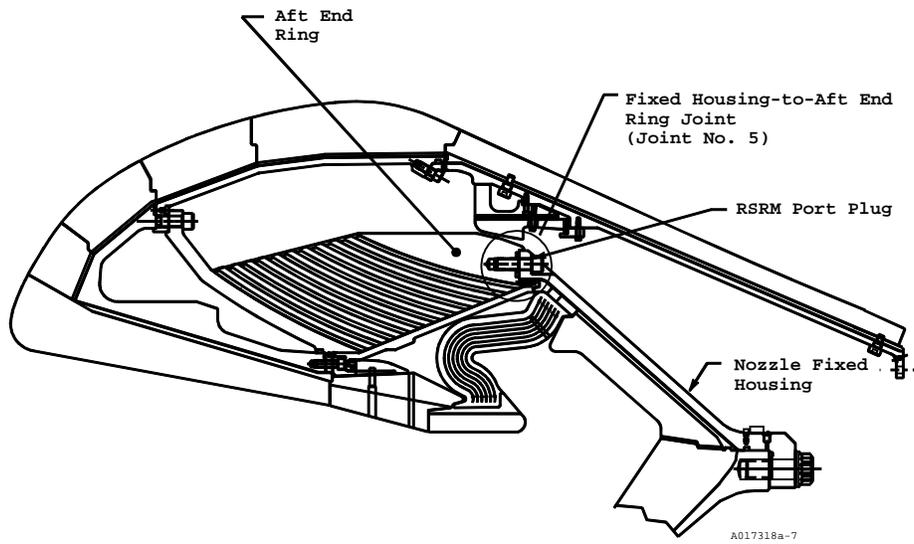


Figure 1. Fixed Housing-to-Aft End Ring Joint, Metal Components Locations

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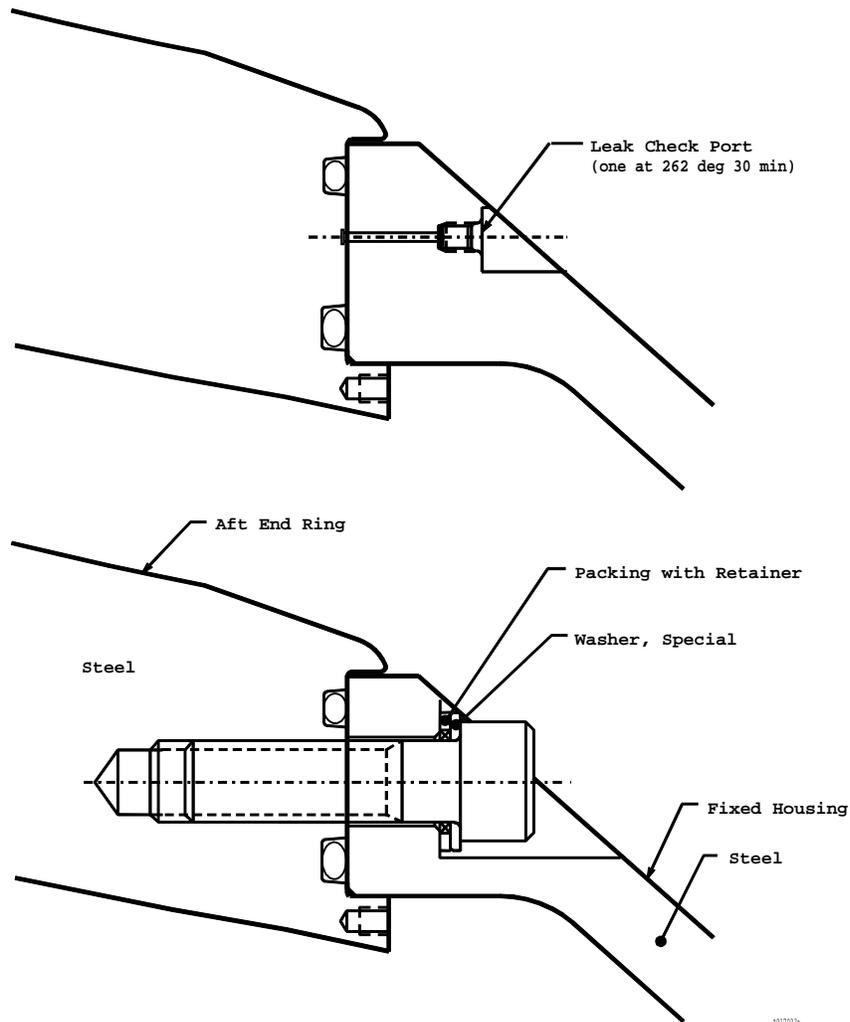


Figure 2. Fixed Housing Assembly-to-Aft End Ring Joint, Metal Components

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9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN FAILURE CAUSES

- | | |
|-------|--|
| A | 1. Aft end ring dimensions are per engineering drawings. |
| B,F | 2. Refurbished aft end ring dimensions are per engineering drawings and specifications. |
| A,B | 3. Surfaces of the aft end ring are protected from corrosion per engineering. |
| A,B | 4. Epoxy-Polyamide Primer and Epoxy-Polyamide Coating (top coating) are applied to the inner surface of the aft end ring per engineering drawings. |
| A | 5. Fixed Housing dimensions are per engineering drawings. |
| B,F | 6. Refurbished fixed housing dimensions are per engineering drawings and specifications. |
| A,B,F | 7. Surfaces of the fixed housing are protected from corrosion per engineering. |
| A,B | 8. Primer and top coating are applied to the inner surface of the fixed housing per engineering drawings. |
| A,F,I | 9. Screw dimensions are per engineering drawings. This is a one-time-use item. |
| A | 10. Washer, Special dimensions are per engineering and this is a one-time-use item. |
| A | 11. The indexing/spring pin meets dimensional requirements per engineering drawings and is a one-time-use item. |
| A | 12. Design dimension tolerances are per TWR-15995 to assure proper operational clearances. |
| C | 13. The basic forging for the aft end ring was evaluated per JSC Specification SE-R-0006 and found to have grain pattern minimizing residual strain considerations as reported in TWR-10709. |
| D,F | 14. Screws are cadmium plated alloy steel that are baked to relieve hydrogen embrittlement per engineering. |
| C | 15. Analysis for useful life of the fixed housing and aft end ring is per TWR-16875. |
| E | 16. The indexing/spring pin is made from Corrosion-Resistant Steel per engineering. |
| E | 17. Design verification analysis shows that materials and geometry of the fixed housing and aft end ring are acceptable for flight per 18764-09. |
| C,F,I | 18. The aft end ring and fixed housing are heat treated D6AC steel forgings. |
| F | 19. D6AC steel has low-to-moderate resistance to stress corrosion per the MSFC-Standard and Material Use Agreement. |
| A,G,J | 20. A light coating of filtered grease is applied to interfacing metal surfaces and holes prior to installation of socket head cap screws. |
| G,J | 21. Socket head cap screws joining the fixed housing to the aft end ring are tightened |

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and torqued per engineering and shop planning.

- G,J 22. Screws are self-locking per engineering drawings.
- G,J 23. Prior to installation, all socket head cap screws must meet cleanliness requirements per shop planning.
- G,J 24. Screw preload and sequencing is per TWR-15995.
- G,J 25. Assembly stresses are minimized as follows:
 - a. Mating surface flatness is per inspection of machining operations
 - b. Threads are cleaned and lubricated prior to assembly
 - c. Assembly bolts are torqued in a prearranged sequence to preload values
- G,J 26. An indexing pin ensures correct component positioning as the fixed housing and aft end ring are mated.
- G,J 27. Guide pins are used to aid in the proper assembly of the fixed housing to the aft end ring per shop planning.
- H 28. Analysis was conducted by Thiokol engineering to assess vibration and shock load response of the RSRM nozzle during transportation and handling to assembly and launch sites per TWR-16975.
- H 29. Handling and lifting requirements for RSRM components are similar to those for previous and current programs conducted by Thiokol per TWR-13880.
- H 30. Transportation and handling of nozzle assembly items by Thiokol is per the Thiokol IHM 29.
- H 31. The RSRM and its component parts, when protected per TWR-10299 and TWR-11325, are capable of being handled and transported by rail or other suitable means to and from fabrication, test, operational launch, recovery or retrieval, and refurbishment sites.
- H 32. Positive cradling or support devices and tie downs that conform to shape, size, weight, and contour of components to be transported are provided to support RSRM segments and other components. Shock mounting and other protective devices are used on trucks and dollies to move sensitive loads per TWR-13880.
- H 33. Support equipment used to test, handle, transport, and assemble or disassemble the RSRM is certified and verified per TWR-15723.
- H 34. The nozzle assembly is shipped in the aft segment. Railcar transportation shock and vibration levels are monitored per engineering and applicable loads are derived by analysis. Monitoring records are evaluated by Thiokol to verify shock and vibration levels per MSFC specification SE 019-049-2H were not exceeded. TWR-16975 documents compliance of the nozzle with environments per MSFC specifications.
- 35. Possibility of fatigue to these parts during their service life was considered as follows:
 - a. Fixed Housing:
 - 1) TWR-16875 includes this part since its design was controlled by cyclic or repeated load conditions. Fatigue analysis was performed for low cycle fatigue, high cycle fatigue, and fracture mechanics. Results of the

A,B,C,D,E,F,I

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- design analysis per TWR-16975 indicate that calculated housing life substantially exceeds the service life requirement. Structural verification analysis per TWR-16975 shows a positive margin of safety based on a factor of safety of 1.4 ultimate and 1.1 on yield.
- F,I 2) The basic forging was evaluated per JSC Specification SE-R-0006 and reported in TWR-10719. The report shows the forging to be free of re-entrant and sharply folded lines and that the principal grain flow is oriented parallel with principal stresses expected.
- b. Aft End Ring:
- A,B,C,D,E,F,I 1) The aft end ring is a fracture control item per TWR-16875. TWR-16875 documents that the aft end ring passes the safe life requirements and will have a positive margin of safety based on a factor of safety of 1.40 ultimate and 1.1 on yield.
- F,I 2) The basic forging was evaluated per JSC Specification SE-R-0006 and reported in TWR-10709. This report shows the forging to be free of re-entrant or sharply folded lines and that the grain flow was parallel to the principal stresses expected.
- K 36. Aft end ring internal threads at the fixed housing-to-aft end ring joint, for new aft end rings, are per engineering drawings. Refurbished aft end rings must satisfy thread requirements per engineering.
- K 37. The aft end ring is proof tested. The aft end ring threads are loaded in this test.
- K 38. Aft end rings are acceptable for use per engineering. Threads are visually inspected for surface contamination, damage, and surface defects. Threads will have no damage or defects greater than that called out in engineering. Threads are inspected after proof testing.
- K 39. Any thread damage repair requires DR/MRB action per the nozzle refurbishment specification. A Material Use Agreement covers the use of helical inserts in D6AC steel. Thiokol performed tests to assure a twenty-use requirement and structural capability of helical inserts in D6AC steel per TWR-18555.
- F,H,I 40. Analysis of carbon-cloth phenolic ply angle changes for the nozzle was performed. Results show that redesigned nozzle phenolic components have a reduced in-plane fiber strain and wedge-out potential per TWR-16975. New loads that were driven by the Performance Enhancement (PE) program were addressed in TWR-73984. No significant effects on performance of the RSRM nozzle were identified due to PE.
- 533 F,H,I 41. Thermal analysis per TWR-17219 shows the nozzle phenolic meets the new performance factor equation based on the remaining virgin material after boost phase is complete. This performance factor will be equal to or greater than a safety factor of 1.4 for the fixed housing assembly per TWR-74238 and TWR-75135. (Carbon phenolic-to-glass interface, bondline temperature and metal housing temperatures were all taken into consideration). The new performance factor will insure that the CEI requirements will be met which requires that the bond between carbon and glass will not exceed 600 degree F, bondline of glass-to-metal remains at ambient temperature during boost phase, and the metal will not be heat affected at splashdown.

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9.2 TEST AND INSPECTION:

FAILURE CAUSES and
 DCN TEST (T) CIL CODE

1. For New Housing, Nozzle-Fixed verify:

A		a.	Thickness	ADV034,ADV034A,ADV035,ADV035A ADV204,ADV205,ADV207,ADV208
A		b.	Flatness	ADV039,ADV040,ADV042,ADV043
A		c.	Diameter	ADV048,ADV049,ADV053,ADV054,ADV055,ADV057
A		d.	Height	ADV069,ADV070
A		e.	Corrosion protection is per specification	ADV090
A		f.	Profile	ADV154,ADV155
A		g.	True position	ADV210A,ADV211,ADV212,ADV212A
A	(T)	h.	Hydroproof test	ADV097
C,D,E	(T)	i.	Elongation	ADV063
C,D,E	(T)	j.	Fracture toughness (K _{IC})	ADV073
C,D,E	(T)	k.	Reduction in area	ADV171
C,D,E	(T)	l.	Ultimate tensile strength	ADV213
C,D,E	(T)	m.	Yield strength	ADV229
C,D,E	(T)	n.	Ultrasonic	ADV222
F,I		o.	Heat treat	ADV085
I	(T)	p.	Material	ADV195

2. For Refurbished Housing, Nozzle Fixed verify:

B		a.	Thickness	ADV036
B		b.	Diameter	ADV050,ADV058
B		c.	Height	ADV071
B		d.	Straightness	ADV152
B		e.	Roundness	ADV176,ADV180,ADV182
B,F		f.	Flatness	ADV197
B,I	(T)	g.	Hydroproof test	ADV092
C,D,E,F	(T)	h.	Magnetic particle	ADV110
E,F,I		i.	Painted surfaces for heat degradation	ADV082

3. For New Aft End Ring verify:

A,K		a.	Correct thread	ADE004,ADE004A
A		b.	Corrosion protection is per specification	ADE005
A,K		c.	Tap drill hole depth	ADE008,ADE008A,ADE074,ADE074A
A,K		d.	Depth of threads	ADE010,ADE010A,ADE011,ADE011A
A		e.	Diameter dimension	ADE012,ADE014,ADE901,ADE903
A		f.	Flatness	ADE023,ADE024
A		g.	Run out of diameter	ADE063,ADE064,ADE902,ADE904
A,K		h.	Hole perpendicularity	ADE071
A,K		i.	True position	ADE077,ADE077A,ADE078,ADE078A
C,D,E	(T)	j.	Elongation	ADE076B
C,D,E	(T)	k.	Reduction of area	ADE076C
C,D,E	(T)	l.	Ultimate strength	ADE076
C,D,E	(T)	m.	Yield strength	ADE076A
C,D,E	(T)	n.	Ultrasonic	ADE080
C,D,E,F	(T)	o.	Magnetic particle	ADE040
F,I		p.	Heat treat	ADE029
I	(T)	q.	Chemical composition	ADE069

4. For Refurbished Aft End Ring verify:

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A	a.	Corrosion protection	ADE005A
A	b.	Diameter dimension	ADE013,ADJ017
A	c.	Thread size	ADE073
A	d.	Diameter roundness	ADJ016,ADJ018
C,D,E (T)	e.	Magnetic particle	ADE037
F,I,K	f.	No unacceptable damaged threads	ADE003

5. For New Nose-Throat-Bearing-Cowl Housing Assembly, Nozzle verify:

A,B,F,G,J	a.	Application of filtered grease to Aft End Ring O-ring grooves prior to assembly	ADQ012
A,B,F,G,J	b.	Application of filtered grease to Housing, Nozzle-Fixed forward end sealing surfaces prior to assembly	ADQ015
A,B,G,H,J	c.	O-ring grooves in Aft End Ring are free from corrosion and contamination prior to assembly	ADQ208
F	d.	All interfacing surfaces of Aft end ring are cleaned per planning requirements prior to installation of O-rings	ADP001
F	e.	Interfacing surfaces of fixed housing are cleaned prior to assembly per planning requirements	AJR000
G,J	f.	Filtered grease is per drawing requirements	ADQ044
G,J	g.	Filtered grease is applied to all noted holes	ADQ041
G,J	h.	Filtered grease is applied to socket head capscrews prior to installation	ADQ043
G,H,J	i.	Sealing surfaces on Housing, Nozzle-Fixed forward end are free from corrosion and contamination prior to assembly	ADQ202
G,J	j.	Socket head capscrews locking device acceptable at installation	ADQ231
G,J	k.	Fixed housing to aft end ring screw is free from contamination and corrosion, prior to installation	ADQ232
G,J	l.	All interfacing surfaces of Aft end ring are cleaned per planning requirements prior to installation of O-rings	ADP001
G,J	m.	Interfacing surfaces of fixed housing are cleaned prior to assembly per planning requirements	AJR000
G,J	n.	Fixed housing to aft end ring screw torquing sequence	ADQ233
G,J	o.	The amount of torque used on each fixed housing to aft end ring screw	ADQ262
G,J	p.	Washer, Special, is installed with radius side toward head of fixed housing to aft end ring screw	ADQ241
H	q.	Seal surface defects (handling damage) are reworked	ADQ069
H	r.	Sealing surfaces of fixed housing for gouges prior to assembly	ADQ203
H	s.	Sealing surfaces of fixed housing for pitting prior to assembly	ADQ204
H	t.	Sealing surfaces of fixed housing for scratches prior to assembly	ADQ205
H	u.	O-ring grooves in Aft End Ring are free from damage prior to assembly	ADQ206
H	v.	Sealing surfaces on Housing, Nozzle-Fixed forward end are free from damage prior to assembly	ADQ207
H	w.	O-ring grooves in aft end ring are free from gouges prior to assembly	ADQ210
H	x.	O-ring grooves in aft end ring are free from pitting prior to assembly	ADQ212
H	y.	O-ring grooves in aft end ring are free from scratches prior to assembly	ADQ214

6. For the New Nozzle Fixed Housing Assembly verify:

A,B	a.	Complete top coat paint coverage of required surfaces	ADS034
A,B	b.	Complete primer coverage of required surfaces	ADS033
A,B	c.	Part is clean and free from damage, foreign material and corrosion prior to paint per engineering	ADS026
H	d.	O-ring and packing with retainer sealing surfaces are finalized	ADR092

7. For New Washer, Special verify:

A	a.	Inside diameter	ACA018
A	b.	Outside diameter	ACA033
A	c.	Radius on inside diameter	ACA019

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A C,D,E	(T)	d. Thickness e. Heat treat tensile strength by hardness check	ACA043 CIC009
8. For New Pin Spring, Tubular, Slotted verify:			
A C,D,E		a. Diameter b. Correct material (CRES 420 or carbon steel as required per engineering)	ADV062A AJR001
9. For New Pin, Spring verify:			
A		a. Length	ADV062
10. For New Nozzle Assembly, Final verify:			
A		a. Sealing compound (polysulfide sealant) application at base of fastener heads.	ADR211
11. For New Bearing Assembly, Nozzle Flexible verify:			
A A K	(T)	a. Epoxy-polyamide coating applied to designated surfaces b. Epoxy-polyamide primer applied to designated surfaces c. Tensile leak test	ADJ108 ADJ110 ADJ064A
12. For Refurbished Bearing Assembly, Nozzle Flexible verify:			
K	(T)	a. Tensile leak test	ADJ064A
13. For New Screw, verify:			
C,D,E,F	(T)	a. Material (chemical and physical properties)	LAA029
C,D,E,F	(T)	b. Breaking strength	LAA030
C,D,E,F		c. Cadmium plating	LAA031
C,D,E,F	(T)	d. Magnetic-particle inspection	LAA032
C,D,E,F	(T)	e. Stress durability testing	LAA033
C,D,E,F		f. Stress relieved	LAA034
C,D,E,F		g. Embrittlement relieved	LAA035
E		h. Locking element	LAA036
A		i. By lot sample, dimensions	AHA000,AHA001
14. For Shipping Kit-Segment verify:			
H		a. EDR unit, proper calibration prior to shipment	AIC003
H		b. EDR unit proper activation prior to shipment	AIC005
H		c. Transportation EDR data is acceptable	RAA232
15. For New Nose-Throat-Bearing-Cowl Assembly verify:			
H		a. Finalization of parts with defects from shipping/handling damage during processing	ADP033
16. For New Segment Assembly, Rocket Motor, verify:			
H		a. O-ring grooves for damage prior to installation of O-ring	AGJ175
H		b. Primary O-ring sealing surface damage does not exceed requirements	AGJ044